Express Mail No. EV194226065US

PATENT APPLICATION OF

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ENTITLED

ALTERNATOR TESTER WITH ENCODED OUTPUT

Docket No. C382.12-0160

ALTERNATOR TESTER WITH ENCODED OUTPUT

BACKGROUND OF THE INVENTION

The present application is a Continuation-In-Part of application Serial No. 10/098,741, filed March 14, 2002 which is a Continuation-In-Part of U.S. patent application Serial No. 09/575,629, filed May 22, 2000, now U.S. Patent No. 6,445,158, which is a Continuation-In-Part of Serial No. 09/293,020, filed April 16, 1999, now U.S. Patent No. 6,351,102; which is a Continuation-In-Part of Serial No. 09/426,302, filed October 25, 1999, now U.S. Patent No. 6,091,245; which is a Divisional of Serial No. 08/681,730, filed July 29, 1996, now U.S. Patent No. 6,051,976, the contents of which are hereby incorporated by reference in their entirety.

The present invention relates to devices for testing an automotive vehicle. More specifically, the present invention relates to a battery charging system tester for an automotive vehicle.

Automotive vehicles include a storage battery for operating electronics in the vehicle and using an electric starter to start the vehicle engine. A battery charging system is coupled to the engine and is powered by the engine when the vehicle is running. The charging system is used to charge the storage battery when the vehicle is operating.

Many attempts have been made to test the battery of the vehicle. One technique which has been pioneered by Dr. Keith S. Champlin and Midtronics, Inc. of Burr Ridge, Illinois relates to measuring the conductance of batteries to determine their condition. This technique is described in a number of United States patents, for example, U.S. Patent Nos. U.S.

Patent No. 3,873,911, issued March 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 3,909,708, issued September 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,816,768, issued March 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,825,170, issued April 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Patent No. 4,881,038, issued November 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Patent No. 4,912,416, issued March 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Patent No. 5,140,269, issued August 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Patent No. 5,343,380, issued August 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Patent No. 5,572,136, issued November 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,574,355, issued November 12, 1996, entitled METHOD AND APPARATUS FOR DETECTION AND CONTROL OF THERMAL RUNAWAY IN A BATTERY UNDER CHARGE; U.s. Patent No. 5,585,416, issued December 10, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,585,728, issued December 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,589,757, issued December 31, 1996,

entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,592,093, issued January 7, 1997, entitled ELECTRONIC BATTERY TESTING DEVICE LOOSE TERMINAL CONNECTION DETECTION VIA A COMPARISON CIRCUIT; U.S. Patent No. 5,598,098, issued January 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Patent No. 5,656,920, issued August 12, 1997, entitled METHOD FOR OPTIMIZING THE CHARGING LEAD-ACID BATTERIES AND AN INTERACTIVE CHARGER; U.S. Patent No. 5,757,192, issued May 26, 1998, entitled METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY; U.S. Patent No. 5,821,756, issued October 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,831,435, issued November 3, 1998, entitled BATTERY TESTER FOR JIS STANDARD; U.S. Patent No. 5,914,605, issued June 22, 1999, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 5,945,829, issued August 31, 1999, entitled MIDPOINT BATTERY MONITORING; U.S. Patent No. 6,002,238, issued December 14, 1999, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,037,751, issued March 14, 2000, entitled APPARATUS FOR CHARGING BATTERIES; U.S. Patent No. 6,037,777, issued March 14, 2000, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,051,976, issued April 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,081,098, issued June 27, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,091,245, issued July 18, 2000, entitled

METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,104,167, issued August 15, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,137,269, issued October 24, 2000, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,163,156, issued December 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,172,483, issued January 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELL AND BATTERIES; U.S. Patent No. 6,172,505, issued January 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,222,369, issued April 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,249,124, issued June 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Patent No. 6,259,254, issued July 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,262,563, issued July 17, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX ADMITTANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,294,896, issued September 25, 2001; entitled METHOD AND APPARATUS FOR MEASURING COMPLEX SELF-IMMITANCE OF A GENERAL ELECTRICAL ELEMENT; U.S. Patent No. 6,294,897, issued September 25, 2001, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY;

U.S. Patent No. 6,304,087, issued October 16, 2001, entitled APPARATUS FOR CALIBRATING ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,310,481, issued October 30, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,313,607, issued November 6, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,313,608, issued November 6, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,316,914, issued November 13, 2001, entitled TESTING PARALLEL STRINGS OF STORAGE BATTERIES; U.S. Patent No. 6,323,650, issued November 27, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,329,793, issued December 11, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,331,762, issued December 18, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Patent No. 6,332,113, issued December 18, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,351,102, issued February 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Patent No. 6,359,441, issued March 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,363,303, issued March 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM, U.S. Patent No. 6,392,414, issued May 21, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,417,669, issued July 9, 2002, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Patent No. 6,424,158, issued July 23, 2002, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,441,585, issued August 17, 2002, entitled APPARATUS AND METHOD

FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Patent No. 6,445,158, issued September 3, 2002, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Patent No. 6,456,045, issued September 24, 2002, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,466,025, issued October 15, 2002, entitled ALTERNATOR TESTER; U.S. Patent No. 6,466,026, issued October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Serial No. 09/703,270, filed October 31, 2000, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 09/780,146,filed February 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Serial No. 09/816,768, filed March 23, 2001, entitled MODULAR BATTERY TESTER; U.S. Serial No. 09/756,638, filed January 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Serial No. 09/862,783, filed May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 09/960,117, filed September 20, 2001, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 09/908,389, filed July 18, 2001, entitled BATTERY CLAMP WITH INTEGRATED CIRCUIT SENSOR; U.S. Serial No. 09/908,278, filed July 18, 2001, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S. Serial No. 09/880,473, filed June 13, 2001; entitled BATTERY TEST MODULE; U.S. Serial No. 09/940,684, filed August 27, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Serial No. 60/330,441, filed October 17, 2001, entitled

ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/348,479, filed October 29, 2001, entitled CONCEPT FOR TESTING HIGH POWER VRLA BATTERIES; U.S. Serial No. 10/046,659, filed October 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Serial No. 09/993,468, filed November 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Serial No. 09/992,350, filed November 26, 2001, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/341,902, filed December 19, 2001, entitled BATTERY TESTER MODULE; U.S. Serial No. 10/042,451, filed January 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE, U.S. Serial No. 10/073,378, filed February 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Serial No. 10/093,853, filed March 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Serial No. 60/364,656, filed March 14, 2002, entitled ELECTRONIC BATTERY TESTER WITH LOW TEMPERATURE RATING DETERMINATION; U.S. Serial No. 10/098,741, filed March 14, 2002, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Serial No. 10/101,543, filed March 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/112,114, filed March 28, 2002; U.S. Serial No. 10/109,734, filed March 28, 2002; U.S. Serial No. 10/112,105, filed March 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Serial No. 10/112,998, filed March 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; U.S. Serial No. 10/119,297, filed April 9, 2002, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 10/128,790,

filed April 22, 2002, entitled METHOD OF DISTRIBUTING JUMP-START BOOSTER PACKS; U.S. Serial No. 60/379,281, filed May 8, 2002, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE; U.S. Serial No. 10/143,307, filed May 10, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 60/387,046, filed June 7, 2002, entitled METHOD AND APPARATUS FOR INCREASING THE LIFE OF A STORAGE BATTERY; U.S. Serial No. 10/177,635, filed June 21, 2002, entitled BATTERY CHARGER WITH BOOSTER PACK; U.S. Serial No. 10/207,495, filed July 29, 2002, entitled KELVIN CLAMP FOR ELECTRICALLY COUPLING TO A BATTERY CONTACT; U.S. Serial No. 10/200,041, filed July 19, 2002, entitled AUTOMOTIVE VEHICLE ELECTRICAL SYSTEM DIAGNOSTIC DEVICE; U.S. Serial No. 10/217,913, filed August 13, 2002, entitled, BATTERY TEST MODULE; U.S. Serial No. 60/408,542, filed September 5, 2002, entitled BATTERY TEST OUTPUTS ADJUSTED BASED UPON TEMPERATURE; U.S. Serial No. 10/246,439, filed September 18, 2002, entitled BATTERY TESTER UPGRADE USING SOFTWARE KEY; U.S. Serial No. 60/415,399, filed October 2, 2002, entitled QUERY BASED ELECTRONIC BATTERY TESTER; and U.S. Serial No. 10/263,473, filed October 2, 2002, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/415,796, filed October 3, 2002, entitled QUERY BASED ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/271,342, filed October 15, 2002, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 10/270,777, filed October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Serial No. 10/310,515, filed December 5, 2002, entitled BATTERY TEST MODULE; U.S. Serial No. 10/310,490, filed

December 5, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/310,385, filed December 5, 2002, entitled BATTERY TEST MODULE, U.S. Serial No. 60/437,255, filed December 31, 2002, entitled REMAINING TIME PREDICTIONS, U.S. Serial No. 60/437,224, filed December 31, 2002, entitled DISCHARGE VOLTAGE PREDICTIONS, U.S. Serial No. 10/349,053, filed January 22, 2003, entitled APPARATUS AND METHOD FOR PROTECTING A BATTERY FROM OVERDISCHARGE, U.S. Serial No. 10/388,855, filed March 14, 2003, entitled ELECTRONIC BATTERY TESTER WITH BATTERY FAILURE TEMPERATURE DETERMINATION, U.S. Serial No. 10/396,550, filed March 25, 2003, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/467,872, filed May 5, 2003, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE, U.S. Serial No. 60/477,082, filed June 9, 2003, entitled ALTERNATOR TESTER, U.S. Serial No. 10/460,749 (C382.12-0162), filed June 12, 2003, entitled MODULAR BATTERY TESTER FOR SCAN TOOL, U.S. Serial No. 10/462,323, filed June 16, 2003, entitled ELECTRONIC BATTERY TESTER HAVING A USER INTERFACE TO CONFIGURE A PRINTER, U.S. Serial No. 10/____________(C382.12-0147), filed June 23, 2003, entitled CABLE FOR ELECTRONIC BATTERY TESTER, U.S. Serial No. 10/_________(C382.12-0148), filed June 23, 2003, entitled BATTERY TESTER CABLE WITH MEMORY, which are incorporated herein in their entirety.

With the advent of accurate battery testing, it has become apparent that in some instances the battery in the vehicle may be good, and a problem related to the battery charging system is the cause of the perceived battery failure. A vehicle charging system generally includes the battery, an alternator,

a regulator and an alternator drive belt. In most modern vehicles, the regulator is built into the alternator housing and is referred to as an internal regulator. The role of the charging system is two fold. First, the alternator provides charging current for the battery. This charging current ensures that the battery remains charged while the vehicle is being driven and therefore will have sufficient capacity to subsequently start the engine. Second, the alternator provides an output current for all of the vehicle electrical loads. In general, the alternator output, the battery capacity, the starter draw and the vehicle electrical load requirements are matched to each other for optimal performance. In a properly functioning charging system, the alternator will be capable of outputting enough current to drive the vehicle electrical loads while simultaneously charging the battery. Typically, alternators range in size from 60 to 120 amps.

A number of charging system testers have been used to evaluate the performance of the vehicle charging system. These testers generally use an inductive "amp clamp." The amp clamp is placed around a cable or wire and inductively couples to the cable or wire such that the current passing through the wire can be measured. This measurement can be made without having to disconnect the wire. In such a system, typically the operator determines the rated size of the alternator. Next, the operator connects the amp clamp to the output cable of the alternator and an electrical load such as a carbon pile load tester, is placed across the battery. This is a large resistive load capable of receiving several hundred amps which

will force the alternator to provide its maximum output. The maximum output current can then be measured using the amp clamp connection. If the measured output is less than the rated output, the alternator is determined to be malfunctioning. Such a test is cumbersome as the equipment is large and difficult to handle. Further, it is difficult, particularly with compact engines, to reach the alternator output cable. Further, in some cases, the amp clamp may not fit around the output cable. It is also very easy to place the amp clamp around the wrong cable causing a false test.

Another testing technique is described in U.S. Patent No. 4,207,611, which issued June 10, 1980 and is entitled APPARATUS AND METHOD FOR CALIBRATED TESTING OF A VEHICLE ELECTRICAL SYSTEM. The device described in this reference monitors voltage changes present at the cigarette lighter of an automotive vehicle in order to determine the condition of the alternator by applying internal loads such as head lamps and blowers, while the engine is running.

SUMMARY OF THE INVENTION

An alternator tester includes comprising a alternator voltage measurement circuit configured to measure an electrical output of an alternator and a microprocessor configured to determine a alternator condition as a function of the electrical output. The microprocessor further configured to encrypt information provide an encrypted output which is related to the alternator output. A method of testing an alternator includes measuring an alternator electrical output and determining an alternator condition as a function of the alternator output. The

method further includes encrypting data related to the alternator output, and outputting the encrypted data.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a simplified block diagram of an automotive battery charging system tester in accordance with the present invention.

Figure 2 is a simplified flow chart showing steps in a battery test.

Figure 3 is a simplified flow chart showing steps in a starter test.

Figure 4 is a simplified flow chart showing steps in a charging system test.

Figure 5 is a simplified flow chart showing further steps in the charging system test of Figure 4.

Figure 6 is a simplified flow chart showing steps in a diesel engine charging system test.

Figure 7 is a simplified flow chart showing steps to remove surface charge.

Figure 8 is a simplified flow chart showing a ripple test.

Figure 9 is a simplified block diagram showing generation of an audit code in accordance with one aspect of the invention.

Figure 10 is a block diagram of an alternator bench tester in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figure 1 is a simplified block diagram of a battery charging system tester 10 in accordance with one embodiment of the present invention coupled to a vehicle 12. Vehicle 12 includes a battery 14 having positive and negative terminals, an alternator with internal regulator 16, various vehicle loads 18, and a

starter motor 20. In operation, battery 14 provides power to starter 20 and vehicle loads 18 when the engine in vehicle 12 is not running. When the engine in vehicle 12 is running, alternator 16 is used to power vehicle loads 18 and provide a charging current to battery 14 to maintain the charge of battery 14.

Charging system tester 10 includes a microprocessor 30 which controls operation of tester 10 and provides instructions and test result information to an operator through, for example, a display 32. Tester 10 includes a battery testing section 34 which is illustrated generally as conductance amplifier 36. Section 34 operates in accordance with, for example, the conductance based battery testing techniques described in Champlin patents U.S. Patent Nos. U.S. Patent No. 3,873,911, issued March 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 3,909,708, issued September 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,816,768, issued March 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,825,170, issued April 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Patent No. 4,881,038, issued November 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Patent No. 4,912,416, issued March 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Patent No. 5,140,269, issued August 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING

BATTERY/CELL CAPACITY; U.S. Patent No. 5,343,380, issued August 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Patent No. 5,572,136, issued November 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,585,728, issued December 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,598,098, issued January 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Patent No. 5,821,756, issued October 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE. Section 34 is illustrated in very simplified form and conductance amplifier 36 provides an output to an analog to digital converter 38 which is related to the internal conductance of battery 14.

A DC voltage sensor 40 includes voltage scaling resistors 42 and 44 and is coupled to battery 14 to provide an output to analog to digital converter 38 which is representative of the DC voltage across battery 14. Further, an AC ripple detector amplifier 46 is coupled to battery 14 through capacitors 48 and 50 and provides an output to analog to digital converter 38 which is representative of the AC ripple voltage across battery 14.

Microprocessor 30 controls analog to digital converter 38 to select which of the three inputs to digitize. Microprocessor 30 includes firmware, memory, and a software program in accordance with the invention. The user input 54 is coupled to microprocessor 30 to provide the information to

microprocessor 30 from an operator.

Preferably, tester 10 is portable such that it may be easily moved between vehicles or otherwise transported. Portability of tester 10 is achieved because tester 10 does not require large internal carbon pile loads to load the battery charging system. Instead, as described herein, tester 10 utilizes loads internal to the vehicle 12 in testing the charging system. Further, the battery tester performed by tester 10 is in accordance with the non-load battery testing technique as described above.

Figures 2-8 are simplified block diagrams illustrating steps in accordance with the invention. User input for the steps can be through user input device 54 and a display can be provided through display device 32. In Figure 2, block diagram 100 begins at start block 102. At block 104 the type of vehicle test is selected. If it is an in-vehicle test, control is passed to block 106. If it is an out of vehicle test, control is passed to block 120. At block 106, the user is prompted to input the battery rating standard to be used for the test. Various standards include SAE, DIN, IEC, EN, JIS or a battery stock number. At block 108, the user is prompted to input the battery rating according to the selected standard. A battery test is then performed at block 110, the results of the battery test are displayed including battery voltage, battery cold cranking amps, and a general condition of the battery such as good, good but recharged, charged and retest, replace battery or bad cell-replace. Any type of battery test may be used, however, conductance, resistance, impedance or admittance based testing as described in

the Champlin and Midtronics patents is preferred.

Figure 3 is a simplified block diagram 118 for an in-vehicle test. When the user initiates a starter test, for example through an input through user input 54, control is passed to block 124 and the operator is instructed to start the engine. Microprocessor 30 detects that the engine is being started by monitoring the resultant in drop in voltage across battery 14. The starting voltage is measured at block 126. Once the engine starts, and the voltage begins to rise, the tester 10 will display one of four different test results. At block 128, if the starting voltage is low and the battery is discharged, the message "charge battery" is displayed at block 130. At block 132, if the starting voltage is low and the battery has a full charge, the message "cranking voltage low" is displayed at block 134 along with the measured voltage. If at block 136, the starting voltage is normal and the battery has a full charge, block 138 displays cranking voltage normal along with the measured voltage. If, at block 140, the battery test result was either replaced or bad cell, block 142 displays the message replace battery. The low and normal cranking voltages can be selected as desired and using known techniques.

Figure 4 is a block diagram 150 which illustrates steps in a charging system test in accordance with another aspect of the invention. At block 152, the procedure is initiated by the operator while the engine in vehicle 12 is running. At block 154, the voltage across battery 14 due to alternator 16 is measured and displayed. The operator may press and enter button on user input 54 to continue

operation and at block 156 the operator is instructed to turn off all vehicle loads and rev the engine for 5 seconds. At block 158, the revving of the engine is detected by monitoring the AC ripple across battery 14 using ripple detection amplifier 46. If, after 30 seconds, microprocessor 30 does not detect engine revving, control is returned to block 156 and the procedure is repeated. At block 160, the engine revved voltage is measured and control is passed to block 162 where the operator is instructed to turn loads within the vehicle (i.e., headlights, fans, etc.) on and idle the engine. Again, an enter key on user input 54 is pressed and control is passed to block 164 and tester 10 measures the load on, engine idle voltage. At 166, the user is instructed to rev the engine with the loads on and another voltage is obtained at block 168. Control is then passed to block 170 in Figure 5 and it is determined whether the engine speed has increased. At block 172, if there is no charging voltage, that is i.e., the charging voltage is less than or the same as the idle voltage, an output is displayed. Similarly, if the charging voltage is low such that the total voltage across the battery is less than, for example, 13 volts, an output is displayed. At block 176, if a high charging voltage is detected, such as more than 2.5 volts above the idle voltage, an output is displayed. When control reaches block 178, an output is provided indicative of the diode ripple voltage. This voltage can be obtained during any of the measurements where the engine is revved. If the ripple voltage is greater than, for example, 130 mV, an indication is provided that there is a diode or a stator problem.

Figure 6 is a block diagram of a diesel test algorithm 250. If the tester 10 does not detect a charging or a ripple voltage, the tester begins the diesel test algorithm shown at 250. This allows the glow plugs of a diesel engine to turn off. If, at any time during the procedure, a charging voltage and a ripple are detected, the normal test procedure will resume. At block 252, the user is asked to input information as to whether the engine under test is a diesel engine. If the engine is not a diesel engine, a charging system problem is indicated. If the engine is diesel, control is passed to block 254 and a post heating delay, such as 40 seconds, passes at block 256, if there is a post heating or glow plugs off condition, then a charging system problem is indicated. If there is a post heating or glow plug on condition, the operator is instructed to warm up the plugs and retest, or check the glow plugs.

Additionally, the tester 10 can receive a temperature input from the operator and adjust the battery test appropriately.

If the battery test indicates that the battery may have been charged before testing, the user is prompted to indicate whether the test is being performed before charging the battery or after charging the battery and the system is retested.

If the tester 10 determines that the battery may have surface charge, the operator is instructed to turn on the vehicle head lights as indicated in flow chart 300 at block 302. If a drop in voltage is detected at block 304 indicating that the head lights have been turned on, control is passed to block 306. If, however, the head lights have not been turned on,

control is returned to block 302. At block 306, the system is retested. Flow chart 320 of Figure 8 shows a noise detection algorithm. If excessive ripple is detected during engine idle periods at block 322, the operator is instructed to check system loads at block 324. At block 326, the system is retested.

Based upon the test, an output can be printed or otherwise provided to an operator indicating the results of the battery test, the battery rating, the actual measured battery capacity, the voltage, the voltage during cranking and whether the cranking voltage is normal, the condition of the charging system along with the idle voltage and the load voltage and the presence of excessive diode ripple.

In general, the present invention provides the integration of an alternator test with a battery test, an alternator test with a starter test, a starter test with an battery test, or an alternator test with a battery test and with a starter test. The invention allows information from any of these tests to be shared with the other test(s).

In one aspect, tester 10 measures the voltage across battery 20. Both the AC and DC voltages are recorded. The AC voltage is used to identify alternator diode and stator faults. The DC voltage measurement is used to determine if the charging system is functioning properly. The electrical loads of the vehicle are used to load the alternator for convenience. However, other types of loads can also be applied. The tester continually monitors the charging voltage across the battery. The operator is instructed to turn on vehicle loads and

rev the engine. The charging voltage is recorded with the engine revved. In a properly functioning charging system, this charging voltage should be greater than the measured battery voltage with the engine off. This indicates that current is flowing into the battery and thus the battery is being charged even with loads applied to the charging system. This testing principle does not require knowledge of the alternator size, or even the amount of current that the alternator is producing. In the testing, various DC voltages across the battery are measured including battery voltage with the engine off (stead state voltage), battery voltage with the engine running at idle (idle voltage), battery voltage with the engine revved, for example between 1,000 RPM and 2,500 RPM, and the vehicle loads off and battery voltage with the engine revved and vehicle loads on. The AC voltage across the battery which is measured with the engine running is used to detect excessive ripple which may be caused by a faulty diode or stator. Ripple of over about 130 mV is indicative of a diode or stator problem. Additionally, the ripple can be used by tester 10 to detect changes in engine RPM.

An initial revving of the engine can be used prior to returning to idle to ensure that the alternator field circuit is excited and conducting current. If the idle voltage with the loads off is less than or equal to the steady state voltage, then a charging problem exists. If the charging voltage exceeds the steady state voltage by more than, for example, .5 volts, then a regulator problem is indicated.

With the engine revved and the vehicle loads

(such as head lights, blower, rear defrost, etc.) turned on, the revved and loaded voltage across the battery is recorded and compared to the steady state battery voltage. If the charging voltage with loads turned on while the engine is revved is not greater than the steady state voltage, then current is not flowing into the battery and the battery is not being charge. This indicates a problem and that the alternator cannot meet the needs of the vehicle while still charging the battery.

With the present invention, the battery test can be used to prevent incorrectly identifying the charging system as being faulty. Thus, the battery test ensures that a good battery is being charged during the charging system test. The measurement of the cranking voltage while the engine is being started is used to determine whether there is a starter problem. In diesel engine applications, the charging system voltage is measured to determine if the engine glow plug operation is effecting the charging system test result. A long cabling (i.e., 10 to 15 feet) can be used such that the tester 10 can be operated while sitting in the vehicle. The battery testing is preferably performed by measuring the conductance, impedance, resistance or admittance of the battery. Further, the battery test with the engine off can be compared with the battery test with the engine on and used to diagnosis the system.

Another aspect of the present invention relates to the generation of an "audit code" based upon the results of a test. As used herein, the term audit code refers to an encrypted code which contains information about a test performed on an electrical

system of a vehicle. Such information can be particularly useful in monitoring the operation and usage of test equipment. For example, if the present invention is used to test automobiles and warranty claims are then submitted to a manufacturer based upon the results of a test, the present invention can output an audit code after the completion of the test. A manufacturer can decrypt the audit code and reject a warranty claim if the audit code indicates the claim has been falsified. The audit code can contain information, in an encrypted format, which relates to the tests which were performed on a particular vehicle. For example, a manufacturer, such as a vehicle manufacturer, can audit the test(s) performed on a vehicle to reduce the occurrence of warranty fraud. Warranty fraud can occur when an unscrupulous operator attempts to falsify test results in order to return a properly functioning component or to receive payment for services which were not actually performed on a vehicle. Warranty fraud can cost a manufacturer a great deal of money and also lead to misdirected research and development efforts in an attempt to correct defects which do not actually exist. In such an embodiment, any of the tests performed by the present invention or measurements obtained by the invention can be included in the audit code. More generally, the audit code of the present invention can be formed using the results of any starter motor test, alternator test, battery test or a AC ripple test. In a general embodiment of this aspect of the present invention, the particular testing technique used to obtain the test results may be any appropriate technique and is not limited to be specific techniques

set forth herein.

Figure 9 is a simplified block diagram 350 showing steps in accordance with generation of an audit code of the present invention. The steps set forth in block diagram 350 are typically carried out by, for example, a microprocessor such as microprocessor 30 shown in Figure 1. However, the steps may be implemented in hardware, software or their combination as appropriate.

Block 352 illustrates the general step of outputting test results. The test results can be, for example, the results of a starter test, alternator test, battery test or diode ripple test. At block 354, the microprocessor 30 retrieves the data which will be used in the audit code. As discussed herein, such data can comprise many different types of data including rating, operator or user identification, test data or results, etc. For example, this data can be retrieved from memory associated with the microprocessor. At block 356, microprocessor 30 generates an audit code based upon the retrieved data in accordance with any of the embodiments set forth herein. The audit code is generated using an encryption algorithm. The particular algorithm used can be selected in accordance with the desired level of security. However, for most systems, a transposition offset cipher can be used in which individual data elements are transposed and offset by known amounts. More complex algorithms such as RSA, rotating codes or public key based encryption algorithms can be used if desired. At block 358, the microprocessor 30 outputs the audit code, for example, on display 32. An operator can then copy the audit

code onto a return form, or enter the audit code into a database system of the manufacturer. If the audit code will be handled directly by an operator, the code and encryption algorithm should be such that the output is alphanumeric or in a form which is otherwise easy to copy onto a warranty submission form. Of course, if the code is electronically submitted, for example through a data link, the code can take any form. Such data links include, for example, modem or hard wired links, infrared links, ultrasonic links, bar code outputs, RF outputs, or other techniques for conveying data which are known in the art.

The particular data which is used to form the audit code can be any of the final test results or intermediary measurements (that is, measurements which are used to obtain a final test result) set forth herein. For example, the measured starter voltage during cranking, the starter test result, the measured alternator voltage or voltages, the alternator test result, or the ripple test result can be encoded. Battery condition, state of charge or time to charge information can be encoded. Further, the date of the test can be maintained by microprocessor 30 and can be included in the audit code. Using this information, the test can be audited to determine if the measured alternator voltage or starter voltage could actually result in the encoded test results. Further, by checking the encoded date, it is possible to determine whether the vehicle was even in a repair shop during the test period. The raw data, such as voltage levels or other intermediary measurements, can be used by a manufacturer to collect data regarding the operation of a product. For example, a manufacturer could note

that a particular change to an alternator resulted in a statistically significant drop in alternator voltages as measured in actual vehicles. This could be used in a research and development effort to improve system operation.

Other information which can be encoded into the audit code includes information regarding the make or model of the vehicle or battery, information such as the VIN identifying the vehicle, temperature information, time of day information, an identification which specifies the operator, the identity of the dealer or shop performing the test, data which identifies the test equipment or the software used in the test equipment, system or component ratings or other information entered by an operator, the number or sequence of the test, or other information.

The present invention can be implemented in what is known as a "alternator bench tester." Alternator bench testers are devices which are used to test alternators which have been disconnected and removed from the engine. When performing such a test, a motor can be used to rotate the alternator such that an electrical output from the alternator can be measured. For example, microprocessor 30 shown in Figure 1 can couple to the motor which drives the alternator 16. For example, Figure 10 shows such an embodiment in which a motor 400 under the control of microprocessor 30 is used to drive the alternator 16. Optionally, an electrical load 402 can be coupled to the electrical output of the alternator 16. In some embodiments, microprocessor 30 can control the load 402. Sense circuitry 408 measures the output from the

alternator 16. The circuitry described above can monitor the voltage, current and/or power output magnitudes or signals of the alternator 16 in response to differing speeds of motor 400 and/or differing electrical loads applied by load 402. As discussed above, any of the data collected from such a test or results of such a test can be provided as an encrypted output for use in auditing the alternator bench test. The results or any of the measurements obtained during such a test can also be shown on the display 32 and thereby provided to an operator or otherwise provided as an output.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.